# SMART OPTIMIZATION STRATEGIES FOR GRID-CONNECTED HYBRID SYSTEMS USING DISTRIBUTED POWER FLOW CONTROLLERS

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## ABSTRACT

The primary objective of this paper is to present a framework for the design and modeling of a photovoltaic (PV)-wind hybrid system and its control strategies. The goal of these control methods is to keep the hybrid system's operational needs from changing all the time. At the moment, the distribution of energy is a big part of keeping power reliable in distribution systems in power system networks. This study integrated the proposed hybrid system with a combined photovoltaic and wind energy system. People have suggested maximum power point tracking (MPPT) methods to get the most out of the system that was designed. This study also aimed to enhance the stability of the hybrid system. We introduce a new control strategy called the distributed power flow controller (DPFC) implementation with an optimization technique called the lion optimization algorithm (LOA) technique to make the proposed system's power quality and transient stability better. For the first time, this LOA control method was used with a DPFC controller in a system that was connected to the grid. The control technique was created by using signals from the system's parameters, such as voltage and current. This study employed fuzzy logic and lion optimization techniques to adjust these parameters. We tested the proposed system with controllers in MATLAB/Simulink and compared the results.

***INDEX TERMS: fuzzy logic controller, distributed power flow controller, grid interconnected, lion optimization algorithm, PV system, and wind energy system.***

## I.INTRODUCTION

A power system is made up of a number of connected electrical parts that make,store, send, and use energy. The grid is a common type of electric power system that sends power to a large area. The standard electrical infrastructure includes power lines, generators, and outlets. The power plant makes electricity, which is then sent to the load centers and finally to customers through the power distribution system (DS). Problems with power quality in the distribution system are often much worse than those in the generation and transmission stages [1]. In an ideal power grid, the voltage given to the load would be sinusoidal, with a constant amplitude and no harmonics. Also, the distribution line must provide the load with current that meets the requirements of zero harmonics, unity power factor, and balanced phases. Different kinds of electronic loads connected to the grid cause voltage imbalances, low power factor, and current harmonics [2]. This type of load includes three-phase unbalanced loads, switching loads, reactive loads, nonlinear loads, and so on. Voltage harmonics, sagging and swelling currents, and other things can cause voltage problems. Also, current harmonics caused by nonlinear loads make the grid work less well. Active filtering circuits are used to fix the current imbalance and keep the neutral current in check. The Shunt Active Power Filter (SAPF) is a device that keeps load side current harmonics from affecting supply currents. Quickly injecting shunt current makes it easier to fix harmonics in the load current. The Dynamic Voltage Restorer (DVR) is a device that compensates for harmonics and is connected in series with the power source to protect sensitive loads from changes in voltage on the supply side. Engineers are starting to worry about DPFC because it could give customers clean energy. A [2] says that a DC (Direct Current) connecting capacitor is used to connect the SAPF and the DVR (series compensator). This device protects the load and makes sure that service is always available by making up for problems with the power supply. To get rid of the unwanted harmonics, an electrical connection between the transformer and the DPFC is used. To get rid of harmonics in the system, it is necessary to make a reference signal. There are also a number of ways to make the reference signal.

**1.2 PQ ISSUES**

The PQ issue is frequently associated with non-sinusoidal voltage or current waveforms (Johnson et al., 2016). Power quality drops sharply when non-linear loads are connected to thegrid in a number of common places. Different definitions of the PQ may lead to different interpretations [3]. The designer believes that power quality is reached when the power system has no voltage changes or other problems.

Power quality (PQ) is greatly affected by more nonlinear load use and problems with the power system. Better power quality is important because so many people use digital control systems and electrical appliances. Because these devices are so sensitive to PQ changes, even small changes in PQ can cost a lot of money. Figure 1.1 shows three common PQ problems: voltage sag, current harmonics, and voltage surge.

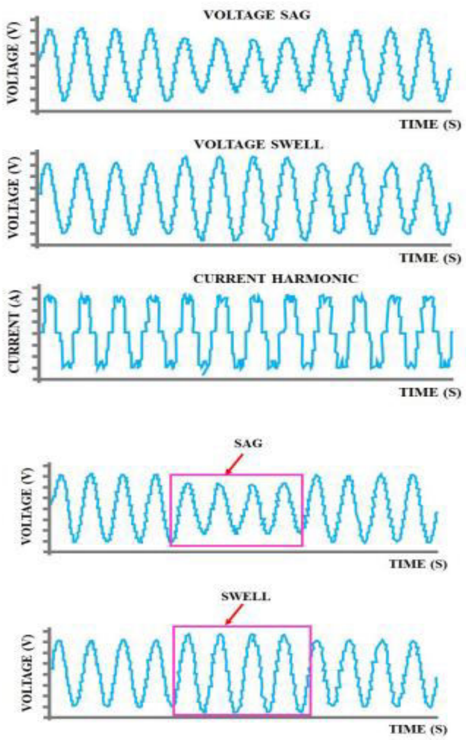



Figure 1.2 (a) Common PQ issues (b) Depiction of Sag and Swell

### 1.2.1 Harmonic Distortion

Harmonic voltage distortion is a type of current distortion that happens when the load current is not sinusoidal. Current harmonics have been caused by a number of modern electronic devices, such as compact uninterruptible power supplies, fluorescent light ballasts, variable speed drives, and switching mode power supplies. Harmonic disturbances are to blame for many problems with how electrical grids work. Some examples of these kinds of problems are circuit breakers tripping without warning, skin effect, transformers overheating, uneven loads, and overloaded neutrals.

### 1.2.2 Voltage Drop

Voltage sag problems are common in the electrical grid and can happen for a number of reasons, such as system failures, powering large loads, and overloading distribution lines. When the voltage drops for a short time, it is called a "sag." Relays, circuit breakers, and sensors (like air flow sensors and water pressure sensors) are especially sensitive to voltage drops.

### 1.2.3 Voltage Increase

Voltage surges, as opposed to voltage sag, are often caused by mistakes in the design. A voltage swell happens when the RMS value of voltage or current suddenly and very quickly rises. A voltage spike can happen when a lot of capacitors are turned on, a big load is suddenly removed, a smaller load is slowly added, or insulation breaks down. It makes data storage less reliable, shortens the life of sensitive devices (or even makes them shut down suddenly), and may even damage the equipment physically.

### 1.3 Effects Of Sensitive And Non-Linear Loads

There has been an increase in the number of non-linear loads, like fax machines, printers, TVs, speed drives, inverters, rectifiers, and so on. Because we use these loads every day, harmonics are building up in the power distribution system, which could damage any devices that are connected to it [4]. One of the most important things that determines how reliable electrical equipment is is how stable the voltage and current waveforms are. When both the fundamental and harmonic waveforms are sinusoidal, the harmonics are taken away from the fundamental as an integral multiple of the fundamental. Some of the problems that can happen when electricaldevices have non-linear loads are motor overheating, more system losses, and broken equipment.

This is why it is so important for electrical engineers to get rid of harmonics from voltage and current waveforms. The power system can also be affected by other problems, like voltage spikes, dips, and flickers. All of these problems could be caused by nonlinear loads putting harmonics into the power line. We will talk about some of the most important effects of harmonics here. Overvoltage in capacitor banks happens when harmonic resonance happens in series and parallel, which can lead to voltage amplification and current multiplication. This can eventually damage the banks. Iron loss in the transformer's magnetic core and eddy current loss in the winding both go up when the voltage is higher than normal. The distorted voltages make the transmission and distribution cables overheat and lose more power. Because the voltages are not sinusoidal, AC motors lose more power through hysteresis and eddy currents.

### 1.4 New Facts Devices

FACTS devices increase the amount of power that can be sent by changing the bus voltage, the phase angle of the transmission line, and the line impedance in real time. The FACTS is a system of flexible AC gearboxes. Power Electronic (PE) components and other static controllers are added to the line of gearboxes to make them more reliable and efficient at transferring power. The Electric Power Research Institute (EPRI) in the United States came up with the idea for FACTS in the early 1980s. FACTS uses electronic power controllers to keep the power grid reliable. The FACTS devices control how power is sent across the grid based on orders from the command center [5].

This feature, which controls bus phase angle, voltage magnitude, and line impedance, means that power distribution systems can work close to their maximum temperatures. Some examples of FACTS controllers are semiconductor devices, iGBTs (insulated-gate bipolar transistors), iIGBTs, and reactors/capacitors with tap-switched quadrature transformers. There are two types of FACTS gadgets: those that use power electronics and those that use other criteria. Thyristor-controlled phase-shifting transformers, static variable compensators, and thyristor- controlled series compensators are all examples of the first type. The static synchronous series compensator (SSSC), the static synchronous compensator (STATCOM), the interline power flowcontroller (IPFC), and the unified power flow controller (UPFC) are all examples of second- generation power flow controllers [5]. Different types of FACTS controllers have unique layouts and features. Category 1 FACTS devices can change their reactive impedance by using thyristor switches to turn the capacitor bank and reactor on and off. The second group, on the other hand, has AC converters that give the gearbox line the reactive power it needs to work and self- commutated DC converters. Because they have so many benefits, VSC-based FACTS controllers are better than current source inverters. VSCs help change the phase angle voltage and impedance of the transmission line by controlling the flow of active and reactive power. Figure 1.2 shows the three kinds of FACTS controllers that can be told apart by how they connect to the bigger network. The SVC and STATCOM are shunt controllers, while the SSSC and TCSC are series controllers. The TCPST and the DPFC are both examples of series-shunt controllers.

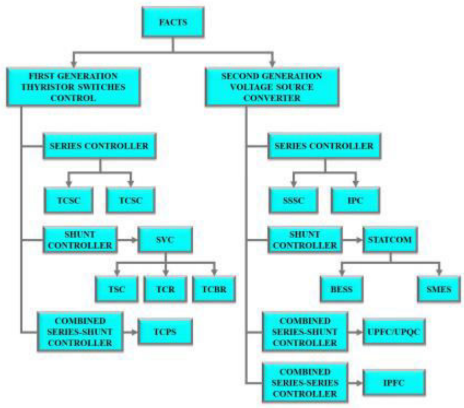
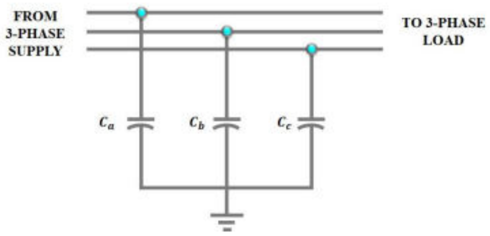



Figure 1.2 FACTS devices classification

The next part talks about some FACTS devices that are often used to fix PQ problems in the distribution network.

### 1.4.1 Banks of Capacitors

Switched capacitor banks make up for reactive power in power distribution networks. There are a lot of problems with using a capacitor bank, even though it's easy to use. These include switching transients, too much power line compensation, being too big, and the effects of aging. Figure 1.3 shows the simplest way to set up this capacitor bank.




### 1.4.2 Static VAR Compensator (SVC)

There are three parts to an SVC: a thyristor-switched reactor-capacitor, a mechanical-switched reactor-capacitor, and a harmonic filter. The properties can be either capacitive or inductive, depending on how the firing angle is set. So, the SVC makes the system more stable during transients, the load's power factor better, and the transmission lines' capacity higher. There are many reasons why SVC isn't used much in DS, including slow response time, low bandwidth, and the need to install a lot of passive components. Figure 1.4 shows the simplest example of SVC

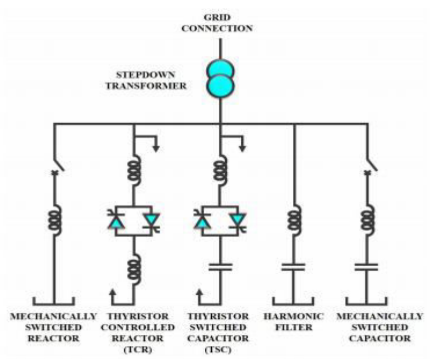



Figure 1.4 Basic illustration of SVC

### 1.4.3Dynamic Voltage Regulator (DVR)

The DVR was made to help fix voltage problems in the power system quickly and cheaply. The basic parts of a DVR are shown in Figure 1.5. A typical DVR might have a DC voltage supply, a VSI, a series transformer, and a harmonic filter. A voltage is sent in series with the distribution line, both in size and phase angle. This makes the load voltage look like a certain sine wave. The DVR can run on its own power when the DC link capacitor is connected to the VSI. It doesn't need batteries or another external power source. The energy optimization method also makes it easier for the DVR to handle power. The DVR does a good job of lowering voltage drops, spikes,

and harmonics, but it can't fix problems with power quality that have to do with current. We also need distributed generation, power sources, battery devices, and external DC voltage sources

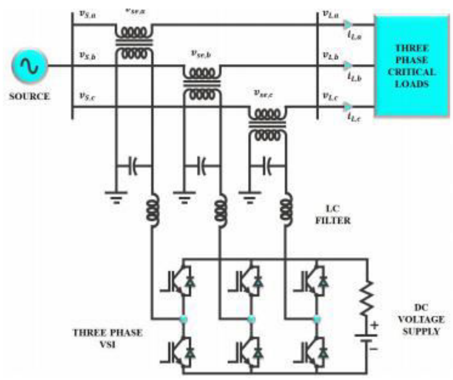



Figure 1.5 Basic structure of DVR

### 1.4.4 DSTATCOM

It could fix the current PQ problems. Figure 1.6 shows how DSTATCOM is set up in a way that is easy to understand. It has a built-in DC link capacitor, voltage regulator, and voltage stabilizer. The DSTATCOM keeps the source current's waveform sinusoidal by injecting a shunt current into the distribution line at a set phase angle and amplitude. It also changes the power factor, reduces harmonics, and does other things by adding the shunt compensatory current. But it can't fix problems with voltage PQ, like sags, surges, and harmonics.

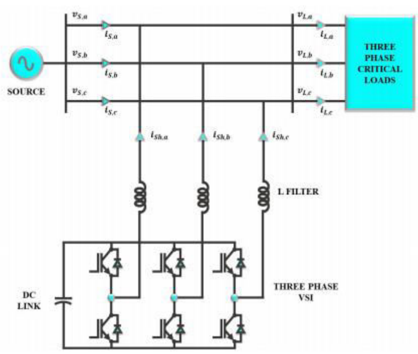



Figure 1.6 Basic design of DSTATCOM

### 1.5 DPFC SYSTEM

The technologies mentioned above only help with specific power quality problems, so their benefits are limited. Because of the PQ problems, these devices can't be used in a Microgrid system. As a result, the DPFC system was made to fix PQ problems on both the supply and load sides. Figure 1.7 shows DPFC's structure in a graph.

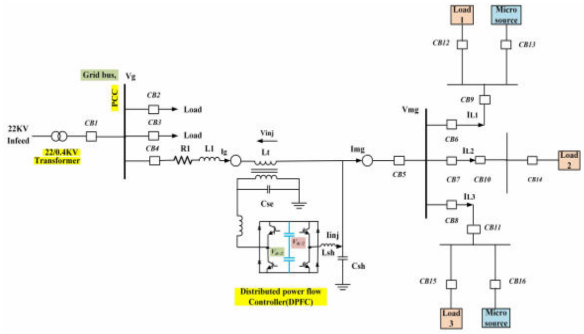



Figure 1.7 Depiction of DPFC

There are two parts to the DPFC procedure. One example is the shunt and series converters that are part of a power electronics converter module. You could also use a series transformer, which adds voltage in a series. A DC connection capacitor connects the SAPF to the DPFC's DVR (series compensator). This device protects the load and makes service more reliable by keeping the power quality steady [6]. The DPFC is a useful tool for improving the PQ of the distribution system because it can fix PQ problems. But the DPFC is still new, so it hasn't been widely used yet. This is because using power converters and transformers makes it much more expensive to make and send DPFC. It is, however, very important to lower the DPFC system's rating without taking away its ability to compensate. This makes DPFC work better and lowers the costs of the system.

**1.6 Dsp-Based Current Generation System For Reference**

Power sinusoids and harmonics, which are made up of low-frequency signals in the power distribution network, happen when there are sudden changes, like load failures and other network problems. To keep supply standards and operations running smoothly at a reasonable cost, you need to keep an eye on and fix PQ problems. It might be hard to understand all the PQ event datathat comes from running big and complicated power systems. When important PQ events happen while a big and complicated power system is running, it becomes very hard to figure out how well it works. So, you need high-tech tools and methods to sort out this PQ event. We use DSP to make a PQ classification method for the DPFC system in this work. It makes the DPFC reference current, which is used to fix power quality problems and adjust sensitive loads.

**1.8 Finding Research Gaps**

The literature review shows that getting rid of harmful current harmonics and meeting the reactive power needs of power systems are the hardest things to do. To fix the problems with passive LC filters, the industry has made Active Power Filters (APF) with more advanced topologies that make the process easier. There are two main types of APFs: shunt filters and series filters. Series AFs fix problems with voltage quality, while shunt AFs fix problems with current waveform distortion. The SSSC and TCSC are part of Series APFs, while the SVC and STATCOM are part of Shunt APFs. You can also find series-shunt filters in TCPST and DPFC. There are basically three kinds of FACTS controllers, and the way they connect to the rest of the system is what makes them different. The way shunt and series APFs are made gives them some unique advantages. This study uses a signal processing technique based on DDSRF theory-based DPFC to make up for the voltage distortions and current harmonics caused by non-linear loads that are very sensitive. This makes it possible to fully comply with the IEEE 519 standard, which says that harmonics must be less than 5%.

**1.9 Problem Statement**

The power DS has a lot of non-linear and sensitive loads, which makes voltage and current harmonics. These can damage devices that are connected to the system. Voltage and current harmonics can cause a lot of problems with power quality, such as voltage sag, swell, flickers, surges, transients, voltage imbalances, and more. People who use energy at all levels are more and more concerned about power quality. We use passive LC filters to get rid of the line harmonics. Passive filters are big, don't fix resonance, and are permanent, which are all bad things. Active power filters (APF), on the other hand, get rid of most of these power supplyproblems. Switched capacitor banks have been used in power distribution networks for a long time to improve power factor, but they have had problems like switching transients and power factor degradation over time. After that, the SVC, DVR, and DSTATCOM are used to fix problems with the power quality in the electrical system. But these gadgets only fix some PQ problems, so their benefits are limited.

### 1.10 Goal Of The Research

The goal of this study is to see how well a DPFC power quality compensator works in real life. The DPFC uses both a series converter and a shunt converter instead of just one power converter like traditional power quality compensators do. Because of this, the system's total cost of production goes up. This is why the DPFC is so popular in business. To raise the DPFC utility rate and keep the manufacturing cost down, it is important to be able to lower the DPFC rating without affecting the power quality compensation. Below, we go into more detail about the main goals of the research. An effective approach to regulating the production of the reference current by employing DPFC to mitigate power quality issues. The DPFC system's design requirements and performance in PQ compensation will be improved by a unique control mechanism. To evaluate the efficacy of DPFC system reference current generation models grounded in SRF theory. Aiming to find out how well models of DPFC systems' reference current generation based on DDSRF theory work. The planned deployment of the DPFC system may become a reality with the help of a DDSRFtheorized signal-processing-based control technique. To show that the suggested method works better, it is compared to other, more established ways of making reference currents and getting harmonics.

### 1.11 Contribution To Research

Using a standardized control method for DPFC to extract current generation and harmonics can improve power quality (PQ) in distribution systems. A good harmonic control strategy could help keep the cost of putting in a DPFC system low. A new way to control signal processing based on DDSRF theory is used to make the DPFC system work.

The simulation results suggestthat the proposed system and control methodology can be effectively executed. The DPFC system's effectiveness is shown by comparing it to other standard control procedures.In the next few sections, we'll talk about all the ways that the signal processing technology we provide is better than traditional methods of general control.

## II.CONCLUSION

Because of the difficulties that come with power quality issues like harmonics, voltage surges and dips, and voltage interruptions, researchers are looking into how to design and install three-Phase DPFC. The DPFC can give the network active power capacity when it is used with PV and an ESS for energy storage. The best thing about combining ESS with DPFC is that it lets you make and use active power from PV. Renewable energy sources are not always reliable because they depend on the outside world. This is where an ESS comes in. In short, ESS and PV combined with DPFC are seen as a possible way to improve the power quality of current distribution systems in distributed generation. People think that this method could lead to good results. The DC-link voltage won't change because the PV-ESS system makes a steady amount of power. Because of this, it may be easier to understand how to control the DC voltage. The system's reliability is tested by putting it through different lighting conditions, voltage changes, and uneven loads. When the load is uneven, the MAF has made d-q control work better. PV- DPFC, which combines dispersed generation with better power quality, could have a big impact on the current distribution infrastructure. After putting the method that was explained into action, harmonic measurements of the grid current showed that it met the IEEE-519 standard. And finally, it's important to stress that the proposed strategy could make the whole electricity grid system more efficient.

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